working paper series
No 99/07

depletion of natural resources and long-term perspectives for the russian economy

Oleg Eismont
Karlygash Kuralbaeva

macro & finance

economic education and research consortium
russia economic research program

CONTENTS

1 INTRODUCTION

The economic problems of resource-exporting countries have been the subject of research since the mid-70s, largely due to the sharp increase in energy prices.[1] The main result of this research is that, contrary to natural expectations, resource-exporting countries may face economic problems, affecting, first and foremost, the manufacturing sector. This effect has been termed the "Dutch Disease", after the country the economy of which experienced the adverse effects of natural gas exports in the 1970s. Works on the "Dutch Disease" can broadly be divided into two groups: those that deal with a short-term analysis versus those that concentrate on the long-term effects of the problem. The overwhelming majority of papers belong to the first group and analyse the short- to medium term effects of a boom in the natural resource sector on other sectors (usually, manufacturing and services). A boom in the natural resource sector, which may be caused by a rise in the world price of a resource, leads to increased income of a country and, consequently, to increased demand for traded and non-traded goods. Since the prices of traded goods are fixed internationally, this effect leads to rising prices of non-traded goods relative to traded ones, which results in labour and capital moving from traded into the non-traded and resource sectors. These effects of squeezing out the manufacturing sector may have some negative effects (e.g. structural unemployment in case of low labour mobility), but in general, from the point of view of the total wealth of a country, the short-term effects of a "Dutch Disease" are positive rather than negative.

However, the long-term consequences of a "Dutch Disease" may go beyond temporary unemployment. One of the surprising features of long-term patterns of economic growth has been the poor performances of resource-rich countries. There are many examples

[1](see, e.g., Aarrestad, 1979; Bruno and Sachs, 1982; Chichilnisky and Heal, 1991; Corden, 1984; Dasgupta et al., 1978; Dasgupta and Heal, 1992; Eastwood and Venables, 1982; Enders and Herberg, 1983; Hartwick and Olewiler, 1986; Rosenberg and Saavalainen, 1998; Sachs and Warner, 1995; Siebert, 1985).

of this phenomenon in the distant past (XVII - XIX centuries), as well as in relatively recent years (1970 - 1990). Long-term analysis of a "Dutch Disease" has been performed in a number of papers (Aarrestad, 1979; Dasgupta et al., 1978; Siebert, 1985) but only recently this phenomenon has been given special treatment (Matsuyama, 1992; Sachs and Warner, 1995). Matsuyama concentrates on the role of land in economic development, while Sachs and Warner analyse the role of mineral resources. Sachs and Warner conducted extensive empirical cross-country research (which included about 100 countries) and obtained convincing arguments that per capita GDP growth rates are negatively correlated with the shares of mineral production and natural resource exports in GDP (Fig. 1). An explanation of this phenomenon (i.e. the relatively low rates of growth of per capita GDP in resource-rich countries) lies in the positive externality resulting from the accumulation of knowledge in the manufacturing sector through learning-by-doing. A booming resource sector, followed by expansion of the non-traded goods sector, leaves the manufacturing sector short of capital and labour and thus slow technical progress. Naturally, for Russia, with its huge energy exports and low competitiveness in the manufacturing sector, the "Dutch Disease" problem is of prime importance.

It should be noted that Russia differs from most resource-exporting countries in that, firstly, it is, unlike, for example, Middle Eastern countries, a highly industrialised country, while, on the other hand, unlike, for example, UK or Norway, its manufacturing sector is not competitive not only in world but also in domestic markets. These peculiarities of the Russian economy could result in more adverse effects of the "Dutch Disease".

In papers that deal with the long-term problems of resource-rich open economies, where the depletion of natural resources is taken into account, extraction costs are assumed to be zero (Aarrestad, 1979; Dasgupta et al., 1978; Siebert, 1985). In this case, the depletion of natural resources is manifested through limited reserves. However, this fixed-stock assumption is rather limiting. As Adelman (1990) puts it: "There is no such thing. The total minerals in the earth is an irrelevant non-binding constraint. If expected exploration-development costs exceed the expected net revenues, investment dries up, and the industry disappears. Whatever is left in the ground is unknown, probably unknowable, but surely unimportant ...". Experience of the exploration of natural resources in Russia supports the above-cited arguments. Existing papers on natural resource economics take account of non-constant extraction costs only in relation to a closed economy (e.g. Solow and Wan, 1976; Heal, 1976; Farzin, 1992; Eismont, 1995).

The paper is organised as follows. The first section deals with a one-sector economy, without taking into account endogenous technical progress, and analyses the effects of stochastic world resource prices, constraints on natural resource export capacities, and foreign assets on the economy of a resource-exporting country. In the second section, two- and three-sector models are considered. The main attention is paid to the effects of positive externality resulting from the accumulation of knowledge in the manufacturing sector of the economy. The long-term effects of the "Dutch Disease" are analysed.

2 ONE-SECTOR ECONOMY

2.1 RESOURCE - EXPORTING COUNTRY WITHOUT FOREIGN ASSETS AND CAPITAL ACCUMULATION

We start with the analysis of a relatively simple problem where domestic capital is constant and there are no investments abroad, so that total income is spent on consumption. To a certain extent, this situation is characteristic of the present state of the Russian economy.

The country possesses natural resources which are used to produce output, according to a neo-classical production function—$F(R, t)$ where R is domestic consumption of natural resources; and for exports E at the world resource price p. Exports of the natural resources of the given country are assumed to be relatively small (as is actually the casefor Russia), so that the world resource price is considered to be given exogenously. The cumulative extraction of the natural resource is subject to a material balance equation

$$\dot{S} = R + E. \tag{1}$$

Extraction costs (per unit of the extracted resource) are assumed to depend on cumulative extraction

$$c_R = \Phi(S), \quad \Phi'(S) > 0, \quad \Phi''(S) > 0. \tag{2}$$

Under this assumption, the natural resource sector is characterised only by extraction costs, so that, even in case of the complete de-industrialisation of the economy, resource extraction would still be possible. This will be extended in section 3.

Then, as long as the natural resource sector accounts for a relatively small fraction of GDP, the total income of a country will be as follows:

$$Y = F(R,t) - \Phi \cdot (R+E) + pE. \tag{3}$$

The problem is to find the trajectories of domestic natural resource consumption and exports which maximise cumulative discounted consumption

$$\max_{R,E} \int_0^\infty [F(R,t) - \Phi \cdot (R+E) + pE] e^{-\delta t} dt, \tag{4}$$

$$s.t.\ \dot{S} = R + E, \tag{5}$$

$$R \geq 0, \tag{6}$$

$$R + E \geq 0. \tag{7}$$

Condition (7) allows for natural resource imports ($E < 0$) up to a level where all domestic consumption of the resource is covered by imports, but forbids stockpiling of imported resource. Usually, instead of (7), condition $E > 0$ is used (see, for example, Dasgupta et al., 1978). If $F'(0,t) = \infty$, condition $R > 0$ is assured.

The current value Hamiltonian for the problem (4)-(7) is

$$H = F(R,t) - \Phi \cdot (R+E) + pE + \lambda(R+E). \tag{8}$$

The first-order conditions for the interior solution will be

$$\dot{\lambda} = \delta\lambda + \Phi'(S)(R+E), \tag{9}$$

$$F_R - \Phi(S) + \lambda = 0, \tag{10}$$

$$-\Phi(S) + p + \lambda = 0. \tag{11}$$

It is easily seen that, due to the concavity of the corresponding functions, sufficiency conditions are also met.
From (10) and (11) it follows that:

$$F_R = p, \tag{12}$$

i.e. the domestic price of the natural resource should be equal to the world price.
Differentiating (11), substituting it into (9) and using (1) yields:

$$\Phi(S) = p - \dot{p}/\delta. \tag{13}$$

Differentiation of (13) leads to:

$$R + E = (\dot{p} - \ddot{p}/\delta)/\Phi'. \tag{14}$$

Next, we assume that the world resource price is rising at a constant rate α

$$\dot{p} = \alpha \cdot p. \tag{15}$$

Thus, to ensure the convergence of the functional (4), condition $\delta > \alpha$ should hold. For that case, (14) will be:

$$R + E = \frac{\alpha(\delta - \alpha)p}{\delta\Phi'} > 0, \tag{16}$$

i.e. along the optimal trajectory, condition (7) holds and, in the optimal solution, there can be no stockpiling of imported natural resource. If $\alpha > \delta$ it would be possible to buy the natural resource on the world market and keep it until its discounted value increased to infinity.

From (16), it follows that the sign of E, i.e. whether the country is an exporter or importer of a natural resource, depends on the dynamics of the ratio $p/\Phi'(S)$. Without technical progress, under increasing resource price and, consequently, $\dot{R} < 0$, if

$$\frac{d}{dt}\left(\frac{p}{\Phi'(S)}\right) > 0, \tag{17}$$

the country will, regardless of its present status, eventually turn into a resource exporter. Under an exponentially growing world price of the resource, it can be shown that, if extraction costs rise no faster than e^S, then the country will be a resource exporter. Next, it is assumed that extraction costs are a power function of cumulative resource extraction:

$$\Phi(S) = AS^{\xi}. \tag{18}$$

In that case, the analytical solution of the problem will be as follows:

$$A(S^{\xi} - S_0^{\xi}) = \frac{\delta - \alpha}{\delta}(p - p_0), \tag{19}$$

$$E = \frac{\alpha(\delta - \alpha)}{\delta}\frac{p}{A\xi S^{\xi - 1}} - R. \tag{20}$$

If the production function is of a Cobb-Douglas type

$$F(R, t) = Be^{\nu t}R^{\gamma}, \quad \gamma < 1, \tag{21}$$

then for a resource-rich country eventually to become a resource importer, the rate of technical progress should be high enough such as to satisfy the following condition:

$$\nu > \alpha\left(1 + \frac{1 - \gamma}{\xi}\right). \tag{22}$$

Thus, the more accessible are the reserves of the natural resource, the higher should be the rate of technical progress for the country to turn into a resource importer.

An important effect of natural resource depletion is the formation of the so-called "exhaustion" rent, accruing to the resource owners. From (3), it follows that the "exhaustion" rent $\rho = p - c_R$ will be

$$\rho = \frac{\alpha}{\delta} p. \tag{23}$$

It should be noted that, in an open economy, exhaustion rent, unlike the case of a closed economy (Eismont, 1996), does not depend on the parameters of the extraction cost function.

2.2 RESOURCE - EXPORTING ECONOMY UNDER STOCHASTIC WORLD RESOURCE PRICE

For an open resource-rich economy, the behaviour of world resource prices is of crucial importance. In general, world commodity prices behave erratically, thus the assumption of an exponential growth in the world price of natural resources is quite a strong one. Next, the effects of the uncertainty of world natural resource prices are analysed. The first problem that has to be solved is how to model the behaviour of world natural resource prices. Though there is no definite empirical support for it in the very long run, usually, resource prices are assumed to follow geometric Brownian motion (Dixit and Pindyck, 1994; Pindyck, 1981). The difference between Pindyck and ourselves is that his analysis was confined to the behaviour of competitive owners, without taking into account the production process or possibilities of the exports of resources. In what follows, these effects (production that uses natural resources and export possibilities) have been taken into account.

The problem is formulated as follows:

$$E_0 \int_0^\infty Y e^{-\delta t} dt \to \max_{R,E}, \tag{24}$$

$$Y = F(R,t) - \Phi(S, R+E) + p(t)E, \tag{25}$$

$$\dot{S} = R + E, \tag{26}$$

$$R \geq 0, \tag{27}$$

$$R + E \geq 0, \tag{28}$$

$$dp = \alpha p\, dt + \sigma p\, dz, \tag{29}$$

where E_0 is expectation based on information at time 0 and dz is the increment of a Wiener process.

We look for an interior solution to the optimisation problem (24)-(29). We define the optimal value function

$$J = J(R, p, t) = \max_{R,E} E_t \int_t^\infty \Pi(\tau)\, d\tau. \tag{30}$$

The Bellman equation is

$$0 = \max_{R,E} \left\{ \Pi(t) + J_t + (R + E) J_S + \alpha p J_p + \frac{1}{2} Jpp \sigma^2 p^2 \right\}. \tag{31}$$

Maximising with respect to R and E gives

$$\frac{\partial \Pi}{\partial R} = -J_S, \quad \frac{\partial \Pi}{\partial E} = -J_S, \tag{32}$$

from where it follows

$$\frac{\partial \Pi}{\partial R} = \frac{\partial \Pi}{\partial E}, \tag{33}$$

and, correspondingly,

$$F_R = p. \tag{34}$$

Differentiating equation (31) with respect to S and using Ito's Lemma yields

$$\frac{\partial \Pi}{\partial S} + \frac{1}{dt} E_t d(J_S) = 0. \tag{35}$$

From (32) and (35), it follows that

$$\frac{\partial \Pi}{\partial S} = \frac{1}{dt} E_t d\left(\frac{\partial \Pi}{\partial R}\right). \tag{36}$$

The goal of the analysis is to obtain an equation describing the expected dynamics of domestic resource consumption and its exports. Substituting

$$\frac{\partial \Pi}{\partial R} = (F_R - \Phi(S))e^{-\delta t} \tag{37}$$

into equation (36) yields

$$-\Phi(S)(R+E) = -\delta(F_R - \Phi) + \frac{1}{dt}E_t(dF_R) - \frac{1}{dt}E_t(d\Phi), \tag{38}$$

from which it follows that

$$\frac{1}{dt}E_t(dF_R) = \delta(F_R - \Phi). \tag{39}$$

It is easily seen that (39) is, actually, Hotelling rule. Using Ito's Lemma, stochastic differential dF_R can be presented as follows:

$$dF_R = F_{RR}dR + F_{Rt}dt + \frac{1}{2}F_{RRR}(dR)^2 + o(dt). \tag{40}$$

Along the optimal trajectory $R = R^*(S,p)$, so that

$$E_t(dR)^2 = \sigma^2 p^2 R_p^2 dt + o(dt), \tag{41}$$

where R_p^2 is the unknown response of optimal resource consumption to a change in price. Next, from (34), (39), (40) and (41), using the expression for expected price dynamics $E_t dp = \alpha p dt$, the following equation describing the expected dynamics of domestic resource consumption can be obtained:

$$\frac{1}{dt}E_t\, dR = \frac{1}{F_{RR}}\left[\alpha p - F_{Rt} - \frac{1}{2}F_{RRR}\sigma^2 p^2 R_p^2\right], \tag{42}$$

which does not depend on extraction cost function $\Phi(S, R+E)$. Note that, in the deterministic case, the corresponding equation is as follows:

$$\frac{1}{dt}dR = \frac{1}{F_{RR}}[\alpha F_R - F_{Rt}]. \tag{43}$$

For a typical neo-classical production function $F_{RR} < 0$ and $F_{RRR} > 0$. Thus, from (42), it follows that, under rates of technical progress that are not too high, uncertainty in world resource prices leads to lower rates of domestic resource consumption than under deterministic prices. In other words, the stochastic character of world prices results in decreasing current domestic resource consumption and increasing future consumption.

In case when the rate of technical progress is high, relative to growth rate of resource price, so that domestic resource consumption increases, uncertainty leads to still higher rates of domestic resource consumption. In other words, stochastic character of world resource prices results in decreasing current domestic resource consumption and increasing its future consumption if time derivative of domestic resource consumption is negative. Reverse effect takes place if time derivative of domestic resource consumption is positive.

Since expected dynamics of domestic resource consumption, in case of uncertainty, does not depend on resource exports and extraction cost function, the expected dynamics of resource exports may be obtained from the solution of the following problem:

$$\max_{E} E_0 \int_0^{\infty} [pE - \Phi(S, R+E)]e^{-\delta t} dt, \tag{44}$$

$$\dot{S} = R + E, \tag{45}$$

$$dp = \alpha p\, dt + \sigma p\, dz, \tag{46}$$

which is, practically, identical to that solved in Pindyck, 1981. Its solution is as follows:

$$\frac{1}{dt} E_t dE = -\frac{1}{\Phi_{EE}} \left[(\delta - \alpha)p - \delta \Phi_E + \Phi_{ES}(E+R) + \Phi_S + \frac{1}{2}\sigma^2 p^2 E_p^2 \Phi_{EEE} \right] \tag{47}$$

Thus if natural resource exports decreases, price uncertainty causes it to decrese more (less) rapidly so that current resource exports gets higher (lower) if marginal resource extraction cost is concave (convex) function of $R + E$.

It should be noted that uncertainty of world resource price influences domestic consumption and exports in a different manner.

2.3 CONSTRAINTS ON NATURAL RESOURCE EXPORTS

Up to now, only constraints on imports of natural resources have been introduced. However, constraints on resource exports may be more important (as, for example, is presently the case in Russia with oil and natural gas). It should be noted that existing papers on the subject neglect this type of constraint.

From (20), it follows that, without export constraints, E is a monotonously increasing function of time. Then, it can be shown that, in the case of constraints on exports ($E \leq E^*$), if in the optimal solution at time t_* exports reach the maximum level E^*, then for $t > t_*$ $E_{opt} = E^*$. Therefore, the optimal trajectory of exports will be ABC, presented in Figure 2. To prove it, let us assume that the optimal trajectory is ABDF. Next, consider trajectory HK, being the part of the optimal one. According to the principle of optimality, HK is a solution of the corresponding unconstrained optimisation problem. However, in this case the optimal control variable is not a monotonously increasing function of time, which contradicts the initial assertion that $\dot{E} > 0$.

If there are constraints on the export capacities of natural resources ($E < E^*$), and

$$0 < E^* < \frac{\alpha(\delta - \alpha)}{\delta} \frac{p}{A\Phi'(S)} - R \tag{48}$$

then, under a Cobb-Douglas production function (with zero rate of technical progress), the optimal trajectory is defined by the following system:

$$\dot{R} = -\frac{\delta}{1-\gamma} R + \frac{\delta \Phi(S)}{B\gamma(1-\gamma)} R^{2-\gamma}, \tag{49}$$

$$\dot{S} = R + E^*. \tag{50}$$

The phase diagram, corresponding to the system (49) and (50), is presented in Figure 3. Trajectories along which domestic natural resource consumption is, eventually, increasing are not feasible since they do not comply with the transversality conditions. It can be shown that there exists an integral curve AB which separates trajectories leading, eventually, to increased domestic consumption, from those along which $\dot{R} < 0$. This separating trajectory is an optimal one since, among all the feasible trajectories, AB has the highest resource consumption under the same S (while exports equals E^*).

It should be stressed that the optimal trajectory exists not for all functions $\Phi(S)$. If, for example, $\Phi(S) = e^S$ then, along any trajectory, domestic consumption, eventually, increases, which violates transversality conditions. There exists, however, a class of functions $\Phi(S)$ for which the optimal trajectory exists and, moreover, its analytical expression can be established. These are the power functions $\Phi(S) = S^k$, where k are integers. If, for example, $\Phi(S) = S^2$, the solution is as follows:

$$R = \left(\frac{1}{\gamma B}\left(S^2 + \frac{2E^*}{\delta}S + \frac{2E^{*2}}{\delta^2}\right)\right)^{-\frac{1}{1-\gamma}}. \tag{51}$$

The solution of the system (49) and (50) in the general case $\Phi(S) = S^k$ is as follows:

$$R = \left(\frac{1}{\gamma B}\left(S^k + \frac{kE^*}{\delta}S^{k-1} + \frac{k^2 E^{*^2}}{\delta^2}S^{k-2} + \ldots + \frac{k!E^{*k}}{\delta^k}S^{k-1}\right)\right)^{-\frac{1}{1-\gamma}}. \tag{52}$$

In case constraints on resource exports are binding, the inequality

$$-\Phi(S) + p + \lambda > 0. \tag{53}$$

holds. Then, using (10), we get

$$F_R = \Phi(S) - \lambda < p, \tag{54}$$

which means that the domestic resource price is lower than the world resource price (as is now observed, for example, in Russia's oil market).

At present in Russia, constraints on energy exports are binding. The problem worth analysing is under what conditions relaxing export constraints, i.e. the construction of new pipelines and sea port oil terminals, is profitable. In formal terms, the marginal benefits of increasing export capacities are defined as follows:

$$MB = -\frac{\partial J}{\partial E^*}, \tag{55}$$

where J is the functional (4). Next a Lagrangian is introduced

$$L = H + \theta(E^* - E). \tag{56}$$

Then it can be shown that

$$\frac{\partial J}{\partial E^*} = \int_0^\infty \theta \, dt. \tag{57}$$

Under conditions of optimality,

$$\frac{\partial L}{\partial E} = p - \Phi + \lambda = 0, \tag{58}$$

which, using (10), yields

$$\theta = p - F_R, \tag{59}$$

where θ is defined in current value terms. Finally, in constant value terms, the marginal benefits from increasing export capacities will be

$$MB = \int_0^\infty (p - F_R)e^{-\delta t} \, dt. \tag{60}$$

At present in Russia, there is wide discussion on the necessity of constructing new capacities for exports of energy resources. To help solve this problem, (60) can be used as a back-of-the-envelope estimate of the marginal benefits of increasing the capacities of oil and natural gas exports. If we assume that the domestic price of a natural resource corresponds to an optimal trajectory then, to estimate the marginal benefits, we need only the world and domestic prices, without the specification of a production function. In 1996, in Russia, the difference between the world and the domestic price of oil was about \$50 per ton. Then, assuming the discount rate is 5%, the marginal benefits of increasing oil export capacities would be more than \$100 per ton of oil per year.

2.4 RESOURCE - EXPORTING COUNTRY WITH FOREIGN ASSETS

Next, we consider a case where part of total income can be invested abroad. Foreign investments K_f yield income at a foreign interest rate r, assumed to be given exogenously. The problem is one of maximising discounted cumulative utility, which is a function of consumption c

$$\max_{R,E} \int_0^\infty u(c)e^{-\delta t}dt, \tag{61}$$

$$\dot{K}_f = F(R,t) - \Phi(S)(R+E) + rK_f + pE - c, \tag{62}$$

$$\dot{S} = R + E, \tag{63}$$

$$K_f(0) = K_{f_0}, \quad K_f(\infty) = 0,$$

$$R \geq 0, \tag{64}$$

$$R + E \geq 0, \tag{65}$$

$$u' > 0, \quad u'' < 0. \tag{66}$$

There are no constraints on foreign assets and capital flows, so negative values of K_f correspond to net borrowing abroad.
The current value Hamiltonian will be

$$H = u(c) + \lambda[F(R,t) - \Phi(S)(R+E) + rK_f + pE - c] + \mu(R+E) \tag{67}$$

First-order conditions for the interior solution are as follows:

$$\dot{\lambda} = \delta\lambda - r\lambda, \tag{68}$$

$$\dot{\mu} = \delta\mu + \lambda\Phi(S)(R+E), \tag{69}$$

$$u' = \lambda, \tag{70}$$

$$\lambda F_R - \lambda\Phi(S) + \mu = 0, \tag{71}$$

$$\lambda(p - \Phi(S)) + \mu = 0. \tag{72}$$

From (71) and (72), it follows that the domestic price equals the world price

$$F_R = p. \tag{73}$$

Differentiating (70) and substituting into (68) yields

$$\eta \frac{\dot{c}}{c} = r - \delta, \tag{74}$$

where $\eta = -\frac{u''(c)c}{u'(c)}$. Equation (74) is the standard condition for inter-temporal consumption efficiency. It should be noted that $r > \delta$.

Differentiating (72), substituting into (69) and using (68), we obtain

$$\dot{p} = r[p - \Phi(S)], \tag{75}$$

which, under an exponentially-growing resource price, yields

$$\Phi(S) = \frac{r - \alpha}{r} p. \tag{76}$$

It should be noted that the foreign interest rate should be greater than the rate of growth of the resource price since, otherwise, there are possibilities for arbitrage (borrowing at r and buying resource).

It can be easily seen that the possibility of foreign investment leads to a solution of the problem similar to that without foreign investment, the only difference being that, instead of the rate of time preference, the foreign interest rate should be used. Thus, the exhaustion rent will be

$$\rho = \frac{\alpha}{r} p. \tag{77}$$

Since $r > \delta$, the liberalisation of capital flows leads to decreasing exhaustion rents and thus to lower profits of the natural resource sectors of the economy.

When resource export constraints are binding, again all the results of the previous section hold, with the foreign interest rate playing the role of a discount rate.

3 MULTI-SECTOR ECONOMY

3.1 THREE - SECTOR MODEL WITH ENDOGENOUS TECHNICAL PROGRESS

The one-sector model which has been analysed so far may be considered as being too aggregate for the problem under consideration, since one of the main effects of the "Dutch Disease" is the sectoral redistribution of the economy.

The aim of this section is to analyse long-term consequences of the "Dutch Disease" within three-sector model. In the above cited paper by Sachs and Warner (1995), devoted to the same problem, two-period, two-sector model has been used. The natural resource sector is viewed only as a supplier of a constant flow of revenues and uses neither labour nor capital. Thus their model captures only the effect of the labour flow from manufacturing to services, ignoring the effect of capital flows from the manufacturing to the resource sector. Besides, a two-period model does not allow for the analysis of the long-term trajectories of economic growth.

In what follows, we present a model which takes into account the development of three sectors: resources, manufacturing, and services. To make the analysis analytically tractable, while retaining the most important aspects of the problem, we assume that the resource sector does not use labour. The non-traded goods sector uses sector-specific capital which is assumed to be constant. All natural resources are exported in exchange for manufactured goods. Besides, it is assumed that there is no depletion of natural resources. The key assumption is that knowledge is being accumulated only in the manufacturing sector as a by-product of the labour and capital used in that sector. This is in line with Mulligan and Sala-i-Martin (1993), which generalises the idea of Uzawa-Lucas (Lucas, 1988), where only labour contributes to the accumulation of knowledge.

The price of the traded good is used as a numeraire. Resource price p_E is given exogenously by the world market. Total labour supply is fixed. Labour is perfectly mobile between manufacturing and services sectors. Capital is assumed to be perfectly mobile between the resource and manufacturing sectors of the economy.

The production functions for the resource sector, manufacturing and services, are $F_E(K_E)$, $F_M(K_M, HL_M)$, $F_S(HL_S)$ respectively, where K_E is the capital used in the resource sector; K_M the capital used in manufacturing; L_M and L_S the labour employed in manufacturing and services, respectively; and H is human capital. The following notations are used: w for the wage; p_S is the price of services; I_M and I_E, respectively, are investments in the manufacturing and resource sectors; r is the interest rate, δ the discount rate, and U the consumer utility function.

A representative agent in the manufacturing sector solves the problem

$$\max_{I_M, L_M} \int_0^\infty (F_M - wL_M - I_M)e^{-rt}dt, \tag{78}$$

$$s.t.\ \dot{K}_M = I_M, \tag{79}$$

which yields as FOC's

$$\frac{\partial F_M}{\partial K_M} = r, \tag{80}$$

$$\frac{\partial F_M}{\partial L_M} = w. \tag{81}$$

A representative agent in the resource sector solves the problem

$$\max_{I_E} \int_0^\infty (p_E F_E - I_E)e^{-rt}dt, \tag{82}$$

$$\dot{K}_E = I_E, \tag{83}$$

which yields

$$p_E \frac{\partial F_E}{\partial K_E} = r. \tag{84}$$

Similarly, for the services sector, the solution of

$$\max_{L_S} \int_0^\infty (p_s F_s - wL_s)e^{-rt}dt, \tag{85}$$

leads to

$$p_s \frac{\partial F_s}{\partial L_s} = w. \tag{86}$$

Labour in the traded and non-traded goods sectors is subject to the constraint

$$L_M + L_S = \overline{L}, \tag{87}$$

where $\overline{L}$ is the total labour supply.

The manufacturing sector produces consumption as well as investment goods. Natural resources can be sold on the world market, in exchange for manufactured goods. Foreign trade is assumed to be balanced. Then, consumption of manufactured goods will be as follows:

$$M = F_M + p_E F_E - I_M - I_E. \tag{88}$$

In addition, the following transversality conditions must be met:

$$\lim_{t \to \infty} \lambda K_M = 0, \tag{89}$$

$$\lim_{t \to \infty} \mu K_E = 0, \tag{90}$$

where λ and μ are co-state variables corresponding to the constraints (79) and (80).

Households solve the problem

$$\max_{M,S} \int_0^\infty U(M, S) e^{-\delta t} dt, \tag{91}$$

under the budget constraint

$$M + p_S S = F_M + p_S F_S + p_E F_E - I_E - I_M. \tag{92}$$

In the case of a Cobb-Douglas utility function

$$U = M^a S^b, \tag{93}$$

the solution of a maximisation problem for households yields

$$a p_S S = bM. \tag{94}$$

Services are used only for domestic consumption

$$S = F_s. \tag{95}$$

Human capital H is being accumulated only in the manufacturing sector, according to the following equation:

$$\dot{H} = A_H K_H^{\alpha_H} (HL_M)^{1-\alpha_H}. \tag{96}$$

This assumption is supported by empirical data that the rates of technical progress in manufacturing sector are significantly higher than in other sectors (e.g. Echevarria, 1997). The case when $\alpha_H = 0$ reduces (96) to the Lucas model of human capital accumulation.

From (96), it follows that human capital accumulation is defined only by domestic factors. It might be argued that, in transition economies, imports of western technologies should be considered as they add to the accumulation of human capital. However, imports of these technologies in Russia is relatively limited as compared to, for example, Central European countries. Technological imports could, nevertheless, be captured by the corresponding increase in A_H.

Next, we assume that all production functions are Cobb-Douglas

$$F_M = A_M K_M^{\alpha_M} (HL_M)^{1-\alpha_M}, \tag{97}$$

$$F_S = A_S (HL_S)^{\beta_S}, \tag{98}$$

$$F_E = A_E K_E^{\alpha_E}. \tag{99}$$

Then the problem can be reduced to solving the following system of differential equations, relative to physical and human capitals:

$$\dot{K}_M = a_1 K_M - a_2 H + d e^{\frac{\pi}{1-\alpha_E} t}, \tag{100}$$

$$\dot{H} = b_1 K_M, \tag{101}$$

where π is the growth rate of the world natural resource price, and

$$a_1 = \frac{r}{\alpha_M} + \frac{a}{b} \cdot r \cdot \frac{1-\alpha_M}{\beta_S} \cdot \alpha_M^{\frac{\alpha_M}{1-\alpha_M}}, \tag{102}$$

$$a_2 = \frac{a}{b}\frac{1-\alpha_M}{\beta_S}\left(\frac{\alpha_M}{r}\right)^{\frac{\alpha_M}{1-\alpha_M}} A_M^{\frac{1}{1-\alpha_M}} \cdot \overline{L}, \tag{103}$$

$$b_1 = A_H\left(\frac{r}{\alpha_M A_M}\right)^{\frac{1-a}{1-\alpha_M}}, \tag{104}$$

$$d = \left(\frac{\alpha_E A_E}{r}\right)^{\frac{1}{1-\alpha_E}}\left(r - \frac{\pi}{1-\alpha_E}\right) p_E^{\frac{1}{1-\alpha_E}}. \tag{105}$$

The solution of the system (100) and (101) is as follows:

$$K_M = C_1 e^{\eta_1 t} + C_2 e^{\eta_2 t} + C_3 e^{\frac{\pi}{1-\alpha_E} t}, \tag{106}$$

$$H = D_1 e^{\eta_1 t} + D_2 e^{\eta_2 t} + D_3 e^{\frac{\pi}{1-\alpha_E} t}, \tag{107}$$

where

$$\eta_{1,2} = \frac{a_1}{2} \pm \sqrt{\frac{a_1^2}{4} - a_2 b_1}, \tag{108}$$

$$C_3 = \frac{d}{\frac{\pi}{1-\alpha_E} + \frac{1-\alpha_E}{\pi} a_2 b_1 - a_1}, \tag{109}$$

$$D_3 = \frac{b_1 d}{(\frac{\pi}{1-\alpha_E})^2 + a_2 b_1 - \frac{\pi}{1-\alpha_E} a_1}. \tag{110}$$

Since the long-term growth rate of the economy should be positively correlated with the rate of human capital accumulation (i.e. with b_1), and taking into account the transversality condition (89), it should be concluded that $C_1 = D_1 = 0$. Then (106) and (107) reduce to

$$K_M = \frac{[H(0) - D_3]\eta_2}{b_1} e^{\eta_2 t} + \frac{\pi D_3}{1-\alpha_E} e^{\frac{\pi}{1-\alpha_E} t}, \tag{111}$$

$$H = [H(0) - D_3] e^{\eta_2 t} + D_3 e^{\frac{\pi}{1-\alpha_E} t}. \tag{112}$$

It can be easily seen that the solution (111) and (112) does not depend on the initial value of capital in the manufacturing sector $K_M(0)$. This is due to the absence of any constraints on investment, so that the capital, at $t = 0$, adjusts instantaneously to its optimal value.

For the transversality condition (89) to hold, one of the following two inequalities (or both) should hold

$$\frac{a}{b\beta_s} < \frac{2\alpha_M - 1}{1 - \alpha_M} \alpha_M^{-\frac{1}{1-\alpha_M}}, \tag{113}$$

$$\frac{a}{b\beta_s} > \left[\frac{a_2 b_1 \alpha_M}{(1 - \alpha_M) r^2} - 1 \right] \alpha_M^{-\frac{1}{1-\alpha_M}}. \tag{114}$$

Transversality condition (90) is met under the condition

$$r > \frac{\pi}{1 - \alpha_E}. \tag{115}$$

Next, the consequences of a sharp rise in the world resource price for the economy of a resource-exporting country are analysed. Let the world resource price at $t = 0$ experience a one-off jump from p_{E0} to $p_{E1} (p_{E1} > p_{E0})$. This jump in the world resource price leads to the following changes of capital in the manufacturing and resource sectors:

$$\Delta K_M = -\frac{\eta_2 r}{a_2 b_1} \left(\frac{\alpha_E A_E}{r} \right)^{\frac{1}{1-\alpha_E}} \left(p_{E1}^{\frac{1}{1-\alpha_E}} - p_{E0}^{\frac{1}{1-\alpha_E}} \right), \tag{116}$$

$$\Delta K_E = \left(\frac{\alpha_E A_E}{r} \right)^{\frac{1}{1-\alpha_E}} \left(p_{E1}^{\frac{1}{1-\alpha_E}} - p_{E0}^{\frac{1}{1-\alpha_E}} \right). \tag{117}$$

Summing up the corresponding changes in exports revenues and outputs of manufactured goods and services, we get a change in GDP, resulting from the rise in the resource price

$$\Delta Y = \left[\frac{1}{\alpha_E} - (1 - \frac{1 - \alpha_M}{\beta_S}) \frac{\eta_2 r}{\alpha_M a_2 b_1} \right] r \times$$

$$\times \left(\frac{\alpha_E A_E}{r} \right)^{\frac{1}{1-\alpha_E}} \left(p_{E1}^{\frac{1}{1-\alpha_E}} - p_{E0}^{\frac{1}{1-\alpha_E}} \right). \tag{118}$$

It can be seen that, with reasonable parameter values, $\Delta Y > 0$. However, under certain, less realistic conditions, (high values of α_M and α_E), the natural resource price rise may result in decreasing GDP.

The qualitative behaviour of the dynamics of GDP, following the upwards jump in the world resource price, is presented in Figure 4.

Thus, for a certain period after the resource price jump, GDP is higher than in the case of no price jumps, although in the long-term perspective the rising world resource price leads to lower rates of economic growth.

3.2 TWO - SECTOR MODEL WITH RESOURCE DEPLETION AND ITS DOMESTIC CONSUMPTION

In the previous section, depletion of natural resources was not taken into account. In Russia, effects of depletion significantly influence resource extraction costs. In what follows, natural resource depletion is analysed within two-sector model comprising resource sector and the rest of economy. The natural resource sector employs no labour and uses only capital as a production factor. The output of the resource sector is used both as an input by the rest of the economy sector and for exports. The production function of the resource sector is as follows:

$$F_E(K_E, Q), \quad \frac{\partial F_E}{\partial Q} < 0, \tag{119}$$

where Q is the cumulative extraction of the natural resource, which is subject to a material balance equation

$$\dot{Q} = R + E, \tag{120}$$

where R is the domestic consumption of the natural resource and E its export.

Economic growth in the model is assumed to be caused by labour-augmenting technical progress, as well as by increasing demand for the resource from the outside world. Technical progress is stimulated by the stock of knowledge which, in its turn, is generated by employment in the rest of the economy sector. There is thus no technical progress in the resource sector, which is in line with the Uzawa-Lucas approach (Lucas, 1988).

The rest of the economy sector is characterised by gross output

$$F_M(K_M, A(t)L, R), \tag{121}$$

where K_M is capital, L labour, and R the consumption of the natural resource.

A decentralised competitive economy is considered.

A representative firm in the rest of the economy sector solves the following maximisation problem:

$$\max_{I_M, R} \int_0^\infty (F_M - pR - p_L L - I_M)e^{-rt}dt, \tag{122}$$

$$\dot{K}_M = I_M, \tag{123}$$

where I_M is investment, p_L wages (relative to the output price of the rest of the economy sector), r the interest rate and p the price of the natural resource (relative to the output price of the rest of the economy sector).

The first-order conditions for problem (122)-(123), under the assumption that there are no constraints on investment, yield

$$\frac{\partial F_M}{\partial K_M} = r, \tag{124}$$

$$\frac{\partial F_M}{\partial R} = p. \tag{125}$$

A representative firm in the resource sector solves the following maximisation problem:

$$\max_{I_E} \int_0^\infty (pF_E - I_E)e^{-rt}dt, \tag{126}$$

$$\dot{K}_E = I_E, \tag{127}$$

$$\dot{Q} = F_E. \tag{128}$$

The first-order conditions for the problem (126)-(128) yield

$$(pe^{-rt} + \mu)\frac{\partial F_E}{\partial K_E} = e^{-rt}, \tag{129}$$

$$\dot{\mu} = -(pe^{-rt} + \mu)\frac{\partial F_E}{\partial Q}, \tag{130}$$

where μ is a co-state variable, corresponding to a constraint (128). Exports of the natural resource are assumed to equal the demand for the resource from the outside world, which is a function of world GDP Y_w and the price of the resource

$$E = E(Y_w, p). \tag{131}$$

Equilibrium in the resource market yields

$$F_E = R + E. \tag{132}$$

Thus, we have a system of equations (124), (125), (128)-(130), (132) for six unknown variables K_M, K_E, R, Q, p, and μ.

Depletion of natural resources is a long-term phenomenon, so an equilibrium growth solution must be sought. To ensure the existence of an equilibrium growth solution, the following specification of production functions and foreign demand for natural resources has been adopted:

$$F_M = A_M e^{\nu\beta t} K_M^{\alpha} L^{\beta} R^{\gamma}, \tag{133}$$

$$F_E = A_E K_E \left(\frac{Q_0}{Q}\right)^{\xi}. \tag{134}$$

Assuming the growth rate of the world GDP equals χ and the income and price elasticities of demand for a resource are, correspondingly, k and ζ, we have

$$E = Be^{\kappa t} p^{-\zeta}, \tag{135}$$

where $\kappa = \chi k$.

It can be shown that there can be two different regimes of equilibrium growth. The first of these regimes corresponds to the relative de-industrialisation of the economy, i.e. when the natural resource sector grows faster than the rest of the economy sector. The second regime corresponds to a balanced equilibrium growth in both sectors, with domestic consumption of the natural resource growing faster than its export. Which of these two regimes is realised depends on the rate of technical progress in the rest of the economy sector. If

$$\nu < \nu_* = \frac{\kappa\xi}{1+\xi\zeta}\left[1+\left(1+\frac{\gamma}{\beta}\right)\xi\right], \tag{136}$$

then the economy faces relative de-industrialisation, i.e. high values for γ and low values for β (which is, actually, the case for Russia) contribute to the threat of de-industrialisation.

If

$$\nu > \nu_*, \tag{137}$$

then the economy will converge to a balanced equilibrium growth.

For the case when $\nu > \nu_*$ we have the following system of equations for the growth rates $g_n = \frac{\dot{n}}{n}$:

$$(1-\alpha)g_{K_M} - \gamma g_R = \nu\beta, \tag{138}$$

$$g_{K_M} - \xi g_Q - g_R = 0, \tag{139}$$

$$g_E/\zeta + \xi g_Q = \kappa/\zeta, \tag{140}$$

$$g_{K_M} - g_R + g_E/\zeta = \kappa/\zeta, \tag{141}$$

$$g_{K_E} - (1+\xi)g_Q = 0. \tag{142}$$

The solution to this system of equations is as follows:

$$g_{K_E} = g_{K_M} = \frac{(1+\xi)\nu\beta}{(1-\alpha)(1+\xi)-\gamma}, \tag{143}$$

$$g_R = g_Q = \frac{\nu\beta}{(1-\alpha)(1+\xi)-\gamma}, \tag{144}$$

$$g_E = \kappa - \frac{\xi\zeta\nu\beta}{(1-\alpha)(1+\xi)-\gamma}. \tag{145}$$

If $\nu < \nu_*$ the system of equations for the growth rates will be

$$(1-\alpha)g_{K_M} - \gamma g_R = \nu\beta, \tag{146}$$

$$g_{K_E} - \xi g_Q - g_E = 0, \tag{147}$$

$$g_E/\zeta + \xi g_Q = \kappa/\zeta, \tag{148}$$

$$g_{K_M} - g_R + g_E/\zeta = \kappa/\zeta, \tag{149}$$

$$g_{K_E} - (1+\xi)g_Q = 0. \tag{150}$$

The solution of this system yields

$$g_{K_M} = \frac{1}{1-\alpha-\gamma}\left(\nu\beta - \frac{\gamma\xi\zeta\kappa}{1+\xi\zeta}\right), \tag{151}$$

$$g_{K_E} = \frac{(1+\xi)\zeta\kappa}{1+\xi\zeta}, \tag{152}$$

$$g_E = g_Q = \frac{\xi\kappa}{1+\xi\zeta}, \tag{153}$$

$$g_R = \frac{1}{1-\alpha-\gamma}\left[\nu\beta - \frac{(1-\alpha)\xi\zeta\kappa}{1+\xi\zeta}\right]. \tag{154}$$

It can be easily seen that, under the condition $\nu < \nu_*$, capital in the resource sector grows faster than capital in the rest of the economy sector, i.e. there is relative de-industrialisation of the economy.

From (129)-(130), the following system of equations can be obtained:

$$\dot{p} = rp - \frac{r^2 Q^\xi}{A_E}, \tag{155}$$

$$\dot{Q} = \gamma A_M \left(\frac{\alpha A_M}{r}\right)^{\frac{\alpha}{1-\alpha-\gamma}} e^{\frac{\nu\beta}{1-\alpha-\gamma}t} p^{-\frac{1-\alpha}{1-\alpha-\gamma}} + Be^{\kappa t}p^{-\zeta}. \tag{156}$$

If $\nu < \nu_*$ then, after introducing new variables

$$x = \frac{Q^\xi}{A_E p}, \tag{157}$$

$$y = \frac{Be^{\kappa t}}{Qp^\zeta}, \tag{158}$$

(155)-(156) reduces to the following system of equations:

$$\frac{\dot{x}}{x} = r^2 x + \xi y - r, \tag{159}$$

$$\frac{\dot{y}}{y} = \zeta r^2 x - y + \kappa - \zeta r. \tag{160}$$

For the steady state of the system (159)-(160) to exist, the following inequality should hold:

$$r > \frac{\kappa\zeta}{1+\xi\zeta}. \tag{161}$$

The steady state values will be

$$x_* = \frac{r - \xi(\kappa - \zeta r)}{r^2(1+\xi\zeta)}, \qquad y_* = \frac{\kappa}{1+\xi\zeta}. \tag{162}$$

The steady state is of a saddle type.
The steady state growth rate of a resource price is

$$\left(\frac{\dot{p}}{p}\right)_* = \frac{\kappa\xi}{1+\xi\zeta}. \tag{163}$$

which increases with increasing ξ.
Scarcity rent, which equals the shadow price of a resource, as a share of a resource price, is

$$\left(\frac{\rho}{p}\right)_* = \frac{\kappa\xi}{r(1+\xi\zeta)}. \tag{164}$$

The assumption that each sector is behaving optimally may not be true in transition economies, due to the poor information that economic agents have about investment possibilities outside their own business. In that case, an alternative assumption is that all profits are reinvested within the same sector (Gomulka and Lane, 1997). Then, the corresponding system of equations will be as follows:

$$\dot{K}_M = s_M(F_M - pR), \tag{165}$$

$$\dot{K}_E = s_E p F_E, \tag{166}$$

$$\dot{Q} = F_E, \tag{167}$$

$$\frac{\partial F_M}{\partial R} = p, \tag{168}$$

$$F_E = R + E, \tag{169}$$

where s_M and s_E are the investment shares in the manufacturing and resource sectors. It can be easily seen that all the above results concerning equilibrium growth hold for the system (165)-(169) as well.

Next, using the above results, the dynamics of GDP, depending on the share of the resource sector, are analysed. From the definition of GDP (in the prices of the rest of the economy sector), it follows that

$$Y = F_M + p_E E. \tag{170}$$

Then, the equilibrium growth rate of GDP will be

$$Z = \left(\frac{\dot{Y}}{Y}\right)_* = \frac{f + h \cdot \varepsilon}{1 + \varepsilon}, \tag{171}$$

where

$$f = \left(\frac{\dot{F}_M}{F_M}\right)_*, \tag{172}$$

$$h = \left(\frac{\dot{p}_E}{p_E}\right)_* + \left(\frac{\dot{E}}{E}\right)_*, \tag{173}$$

$$\varepsilon = \left(\frac{p_E E}{F_M}\right)_* . \tag{174}$$

Index $*$ refers to the equilibrium values. It can be easily seen that

$$sgn\frac{\partial Z}{\partial \varepsilon} = sgn(h - f). \tag{175}$$

Using the corresponding equilibrium values, obtained from the system of equations (138)-(142), it can be found that $h < f$ under the condition

$$\kappa < \kappa_* = \frac{(1 + \zeta\xi)\beta\nu}{(1 - \alpha)(1 + \xi) - \gamma}. \tag{176}$$

Let the rate of technical progress in the rest of the economy sector be high enough so that condition (137) holds. Then, since $\xi > 1$, condition (176) also holds. Thus, even if there is no threat of deindustrialisation, the higher the share of a resource sector, the lower are the growth rates of GDP.

4 CONCLUSIONS

In a small open economy, the natural resource exhaustion rent does not depend on the extraction cost function, which makes this rent much simpler to estimate.

If world natural resource prices are stochastic and follow a geometric brownian process (similar to share prices on a stock exchange), then a resource-exporting country should lower its current domestic resource consumption relative to the deterministic case, and increase its future domestic consumption.

With foreign assets, the optimal policy of a resource-exporting country is the same as in the case of no foreign assets, the only difference being that, instead of the discount rate, the foreign interest rate should be used.

A liberalisation of capital flows leads to diminishing rents of resource owners in a resource-exporting country.

Expanding the export capacities of natural resources in Russia is an economically efficient investment.

A sharp increase in world resource prices, though increasing GDP in a short-term perspective, will result in decreased long-term rates of economic growth of a resource-exporting country. The higher the share of a resource sector in the economy of a resource-exporting country, the lower are its GDP growth rates.

Rising natural resource extraction costs add to the possibility of the de-industrialisation of a resource-rich country.

REFERENCES

AARRESTAD, J., 1979, Resource Extraction, Financial Transactions and Consumption in an Open Economy, *Scandinavian Journal of Economics*, vol. 81, 552–565.

ADELMAN M.A., 1990, Mineral Depletion with Special Reference to Petroleum, *The Review of Economics and Statistics*, vol. 72, 1–10.

BRUNO M., 1982, Adjustment and Structural Change under Supply Shocks, *Scandinavian Journal of Economics*, vol. 84, 199–221.

BRUNO N. and J. SACHS, 1982, Energy and Resource Allocation: a Dynamic Model of the "Dutch Disease", *Review of Economic Studies*, vol. 49, 845–859.

CHICHILNISKY G. and G. HEAL, 1991, *Oil and the International Economy*, Oxford University Press.

CORDEN W., 1984, Booming Sector and Dutch Disease Economics: Survey and Consolidation, *Oxford Economic Papers*, vol. 36(3), 359–380.

DASGUPTA P., R. EASTWOOD, G. HEAL, 1978, Resource Management in a Trading Economy, *Quarterly Journal of Economics*, vol. 92, 297–306.

DASGUPTA P. and G. HEAL, 1979, *Economic Theory and Exhaustible Resources*, Cambridge University Press. DIXIT A. and R. PINDYCK, 1994, *Investment under Uncertainty*, Princeton University Press.

EASTWOOD R.K. and A.J. VENABLES, 1982, The Macroeconomic Implications of a Resource Discovery in an Open Economy", *Economic Journal*, vol. 92, 285–299.

ECHEVARRIA C., 1997, "Changes in Sectoral Composition Associated with Economic Growth", *International Economic Review*, vol. 38, 431-452

EISMONTO., 1995, Economic Growth with Non-constant Natural Resource Extraction Costs, *Ekonomika i Matematicheskie Metody*, vol. 31, No 3, (in Russian).

ENDERS K. and H. HERBERG, 1983, The Dutch Disease: Causes, Consequences, Cure and Calmatives, *Weltwirtschaftliches Archiv*, vol. 119, No 3, 473–497.

FARZIN Y.H., 1992, The Time Path of Scarcity Rent in the Theory of Exhaustible Resources, *Economic Journal*, vol. 102, 813–830.

GOMULKA S. and J. LANE, 1997, Recession Dynamics Following an External Price Shock in a Transition Economy, *Structural Change and Economic Dynamics*, vol. 8, 177–203.

HARTWICK J. and N. OLEWILER, 1986, *The Economics of Natural Resource Use*, Harper–Collins Publishers, New York.

HEAL G., 1976, Relationship Between Price and Extraction Costs for a Resource with a Backstop Technology, *Bell Journal of Economics*, vol. 7, 371–378.

LUCAS R., 1988, On the Mechanics of Economic Development, *Journal of Monetary Economics*, vol. 22, 3–42.

MATSUYAMA K., 1992, Agricultural Productivity, Comparitive Advantage, and Economic Growth, *Journal of Economic Theory*, vol. 58, 317–334.

MULLIGAN C. and X. SALA-I-MARTIN, 1993, Transitional Dynamics in Two-Sector Models of Endogenous Growth, *The Quaterly Journal of Economics*, vol. 108, 739–773.

PINDYCK R. 1981, The Optimal Production of an Exhaustible Resource when Price is Exogenous and Stochastic, *Scandinavian Journal of Economics*, vol. 83, 277–288.

ROSENBERG C. and T. SAAVALAINEN, 1998, How to Deal with Azerbaijans Oil Boom? Policy Strategies in a Resource-Rich Transition Economy, IMF, WP/98/6.

SACHS J. and A. WARNER, 1995, Natural Resource Abundance and Economic Growth, NBER, Working Paper 5398.

SIEBERT H., 1985, *The Economics of the Resource-Exporting Country*, JAI Press Inc.

SOLOW R.M. AND F.Y. WAN, 1976, Extraction Costs in the Theory of Exhaustible Resources, *Bell Journal of Economics*, vol. 7, 359–370.

Figure 1 Dependence of average per capita GDP groth rate(% per year, 1970-1989) on the share of natural resource exports in GDP (Sachs and Warner, 1995)

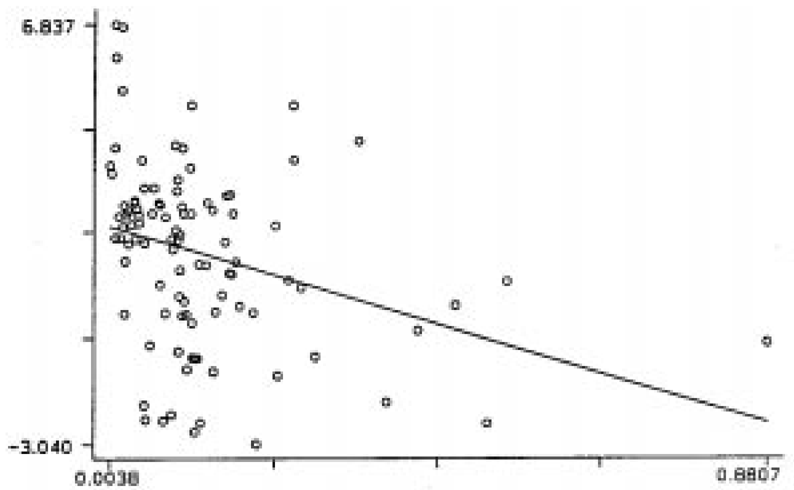

Figure 2. Optimal trajectory of natural resource exports under constraints on exports capacities

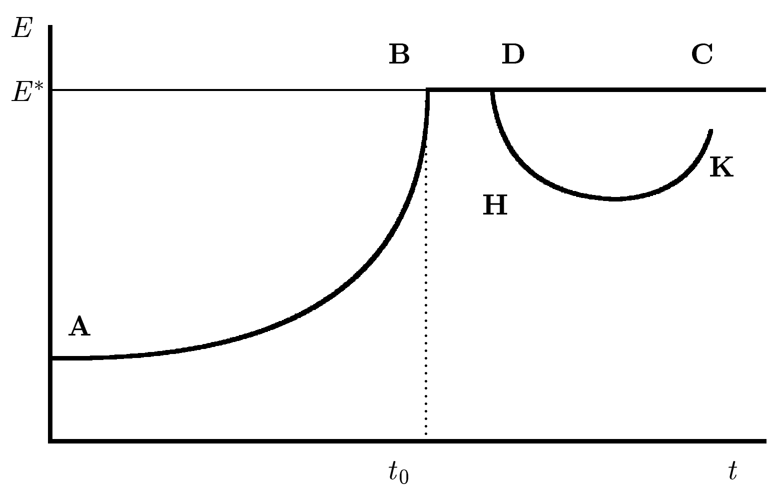

Figure 3. Phase diagram of the system of equations (49), (50)

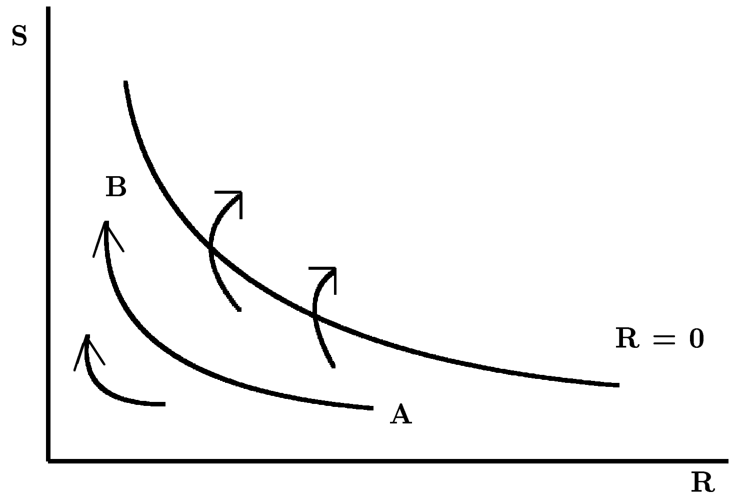

Figure 4. Dynamics of GDP with (ABCE) and without (ABD) world resource price jump